LESSON 37 – ELECTRONIC SUPPORT MEASURES (ESM)
(Pick up Problem Set 5)

With ESAs, we've just looked at emitting radiation with different phases to control the beam's direction. If we could detect the phase of an incoming beam at different points we may be able to determine the location of the source. Can you say "Wild Weasel"?

Reading:
Stimson **Ch. 36**

Problems/Questions:
None

Objectives:
37-1 Know the definition of ESM
37-2 Know the main method used to accomplish ESM
37-3 Understand the physical processes used in interferometry.

Last Time: GR Debrief

Today: Electronic Support Measures
Interferometry
Reverse phased-array
The Mighty Wild Weasel

Equations: $\theta = \arccos(\Delta\phi\lambda/2\pi L) = \arccos(c\Delta t/L)$

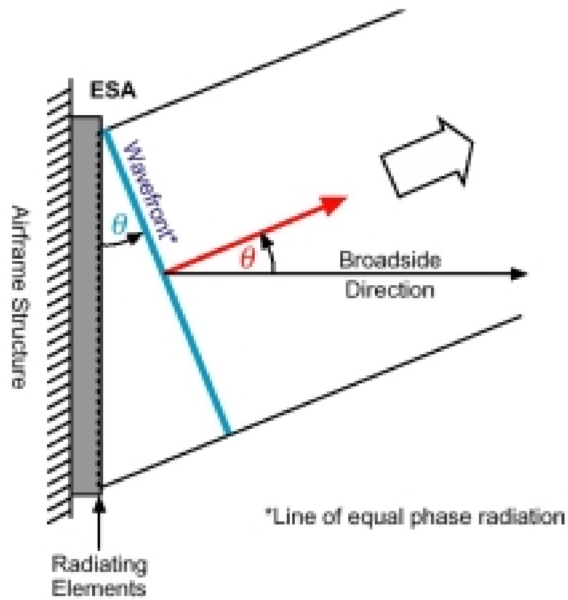
Up until this point, we've been interested in our own radar: figuring out what it could do and where it would point. For the rest of the semester, we'll be discussing ways to defeat radars. The first thing we need to do to defeat a radar is to discover that it's looking at us. After that, we can employ ECM, electronic countermeasures, to give it false information so that we aren't successfully targeted. As the enemy will be trying to do the same thing to us, we'll also need to employ ECCM, or electronic countercounter measures to keep him from limiting our targeting ability. Finally, we can do some things to help ensure that even if he does point his radar at us, he'll never see us. This technique is called stealth. To completely understand stealth, we'll also have to take a short side-trip that will help us understand infrared weapons and sensors. All of this stuff is extremely tactical in nature, and is where we've been headed this whole semester.

For the first problem, we need to detect a radar that might be targeting us. Our problem: given an incoming pulse of electromagnetic energy, determine the direction of the emitter.

Two types of receivers in AF jets let you know the bad guys are looking at you. The first is called RWR, or radar warning receiver. It's on most jets. It lets you know when you're in the *main lobe* of a threat radar and gives you very general range and bearing information. Range info is just based upon how strong the signal is and is VERY rough. The other type of receiver is called a RHAW, or radar homing and warning. It gives VERY precise range and bearing information to the threat emitter, and can even detect *side* and *back lobes* from these radars. These RHAW receivers are only on the F-4G and RC-135. We'll see the theory behind how a RHAW works in this lesson.

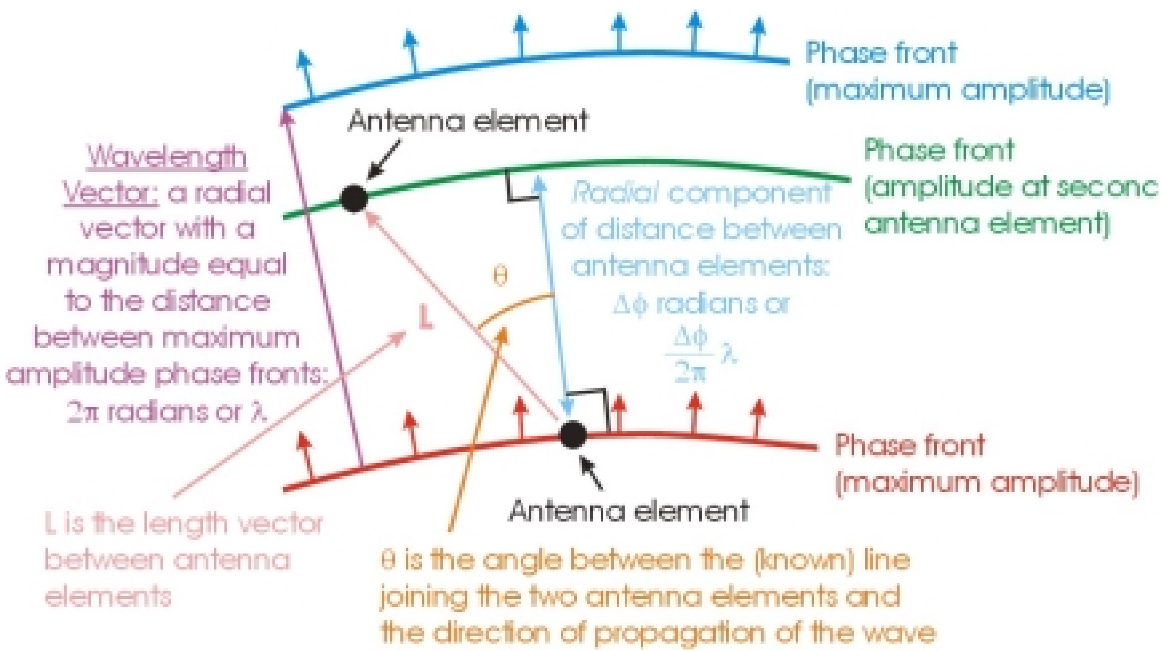
As an overview, and as a perfectly acceptable answer to the question "what is a RHAW?", I'll show you that a RHAW is just a phased-array antenna in reverse!

Show slide of Stimson figure 37.1. The beam is shown propagating at an angle to the broadside direction. How did it get steered that way? We adjusted the phase of each adjacent emitter in the array to vary in a specific way so that the wavefront moved off to the side. The thing to remember about phased arrays is that *phase shift steers the beam.*



What would happen to this diagram if we had an incoming wave instead of an outgoing one? The only things we'd have to reverse are the black and red arrows. The rest of the figure would stay the same. What if, instead of being able to *transmit* waves of different phase, the elements in this antenna were able to *detect* the phase of incoming waves?

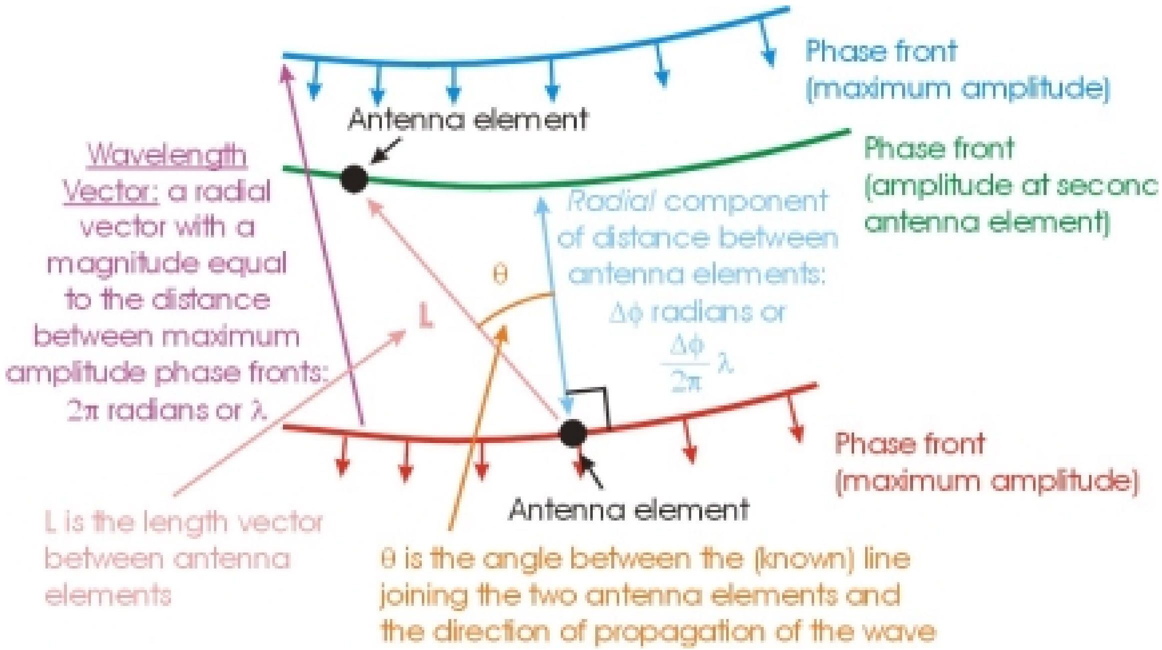
Basically, if you can measure the phase of a pulse simultaneously at two different points, you can find out where it came from! How do we do this? Yes, there's a bit of math involved, but nothing too difficult. The following figure shows the relationship required to calculate the direction of arrival of a wave hitting two antenna elements.



In this figure, **L** = antenna separation vector (known VERY precisely), **λ** = threat radar wavelength vector (determined via data from frequency filters), Δϕ = phase difference between the two antennae (measured), and θ = the angle between **L** and **λ** (calculated).

Only one angle θ will allow Δϕλ/2π to project exactly onto L (demonstrate with a ruler and a meter stick, showing that from certain angles, they look the same length). This geometric relationship gives us what I call the Wild Weasel equation, or $\theta = \arccos\left(\frac{\Delta\theta}{2\pi L}\right)$. The arc cosine function is very sensitive to its argument, so small errors in knowing Δϕ or L mean BIG errors in knowing θ.

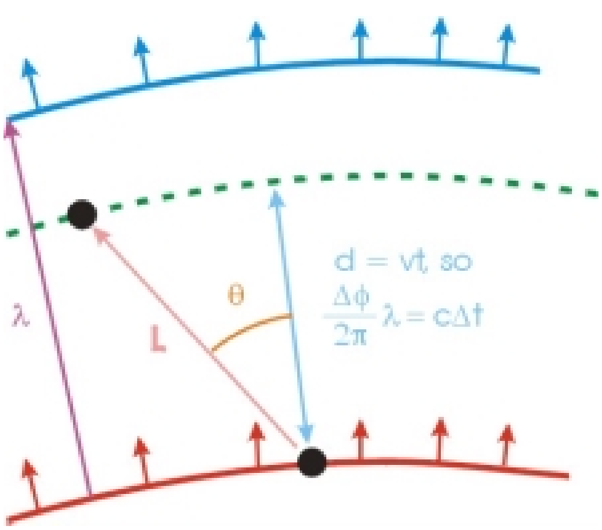
Unfortunately, this only gives a line upon which the emitter must lie. For example, the following figure shows exactly the same L and λ vectors with exactly the same angle θ between them, but the wave is coming from the opposite direction. Thus, with only two antennae, you have a choice of two directions from which the wave could be coming. The only way to eliminate this ambiguity is to add another antenna and do the calculation again.



This result says that to precisely locate an emitter in a single plane, we need a minimum of three antennae. But since we want to locate the source of the wave in three-dimensional space, so we'll need at least 7 antennae (three per plane minus two that are common to two planes).

Show APR 47 slide, showing locations of the antennae on the aircraft, then showing the layout of the antennae in each array. Emphasize the separation of the high/medium band antennae and the separation of the low band antennae. There are 52 antennae on the F-4G used to locate emitters, but all they are really doing is helping you know the phase of the pulse at many points so that we can reconstruct the phase front and determine the direction of arrival of the pulse.

One more problem. It's hard to detect phases. In practice, we really detect the times of arrival of the minimum power (the zero crossings of amplitude) at several points, which gives similar geometry. In this case, the Wild Weasel equation becomes $\theta = \arccos\left(\frac{c\Delta t}{L}\right)$. Again, since the arc cosine function is very sensitive to its argument, small errors in L and Δt mean BIG errors in θ.



In summary, RHAW is a big phased-array in reverse. It uses times of arrival to discover the phase of a wave at several points and then reconstructs the direction of arrival.

Other factors: Threat tables give PRF vs Freq data, so RHAW can identify the signal type and plot its direction.

Now all we know is the direction of arrival of the threat radar's wave. Is this enough for a WW to target the site? Nope, we need range information, too! How can we go about doing this? Discuss sniffing tactics, and let the cadets figure out triangulation on their own.

In summary, ESM (electronic support measures) is the intelligence gathering side of electronic warfare. The receivers we discussed today, RWR and RHAW, are both used in the most immediate form of intelligence, keeping yourself from getting shot. There are other ESM platforms out there that gather the electronic order of battle (EOB) so that mission planners can plan their routes to avoid known SAM sites, as well as other sensors. The common element used in all ESM equipment, however, is the same: an RF (radio frequency) receiver.

Show second half of First In, Last Out.